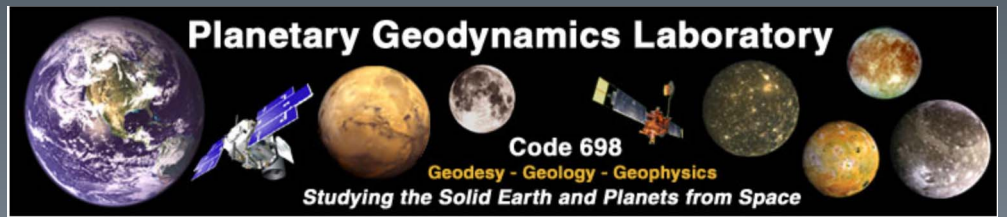
The hazard of impacts from space

Michael Purucker, Planetary Geodynamics Lab, SGT @ NASA, 17 May 2012, Moldavian Risks-1



Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

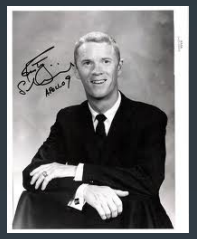
Outline

- Near Earth objects today

1. NASA's latest target, and a short personal history of the field
2. Natural history (origin, life span, size). Bottke standard model
3. Tests of the standard model, Research directions
4. Identification, status, POD, options once identified
5. Mesospheric meteor layer, Research directions

- NEOs yesterday

1. Mass extinctions, and terrestrial impacts
2. Large lunar, Martian, and Hermean impact basins
3. NASA's GRAIL mission



Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

NASA's latest target

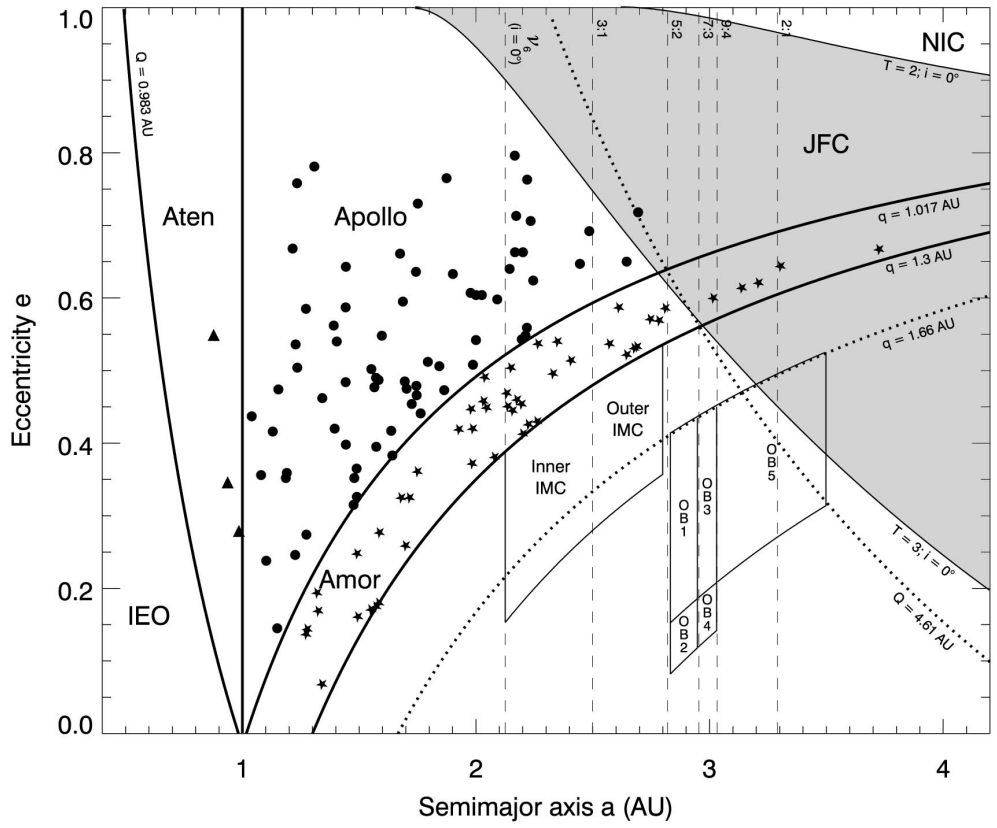
- NEO = NEA + NEC, q<1.3 AU, Q>0.983 AU
- In 2010, US president announced plans to land on an NEA by 2025 (based on 2009 Augustine report)
- NEAs have no substantial gravity well, hence spacecraft that visit can 'easily' return to Earth.
- No viable NEA candidates yet, (3-6 month flight, solid, not spinning, football-field or larger) but they almost certainly exist.
- A short history: Shoemaker's , Meteor crater, US lunar program, me, Helin/Palomar survey, terrestrial impacts, Porco/LP/ashes, Bottke model, Schweickart, NRC Planetary defense task report

Natural history

- Sources: Main asteroid belt, transNeptunian disk
- Mode of disturbance: Resonance, esp Jupiter and Saturn, but also Mars
- Secular evolution: Steady state since 3 Ga
- Dynamical lifetimes: 10 Myr
- Size: dust to objects 10's of km in size
- Classification (Amors, Apollos, and Atens)
- Bottke standard model (Icarus, 2002) postulated 960+-120 NEOs having H (absolute magnitude) <18 and a<7.4. 44% had been found by 2000, with 32%, 62%, and 6% predicted to be Amors, Apollos, and Atens, respectively.

NEA Classification

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space



Standard Model (Bottke et al., 2002)

Numerical integration of test particles from five source regions (4 NEA+1 NEC, no Halley-type comets) created residence time probability distributions in semi-major axis, eccentricity, and inclination. Produced an NEO model population of 960+-120 NEOs with H<18

Status of standard model

- Current population of large NEAs (H<16) has
  - A significantly larger proportion of Amors
  - Significantly smaller proportions of Apollos, Atens, IEOs and PHAs
  - A larger proportion of high-inclination Amors
  - A larger proportion of high-inclination Apollos

Valsecchi and Gronchi, 2011, DPS/EPSC

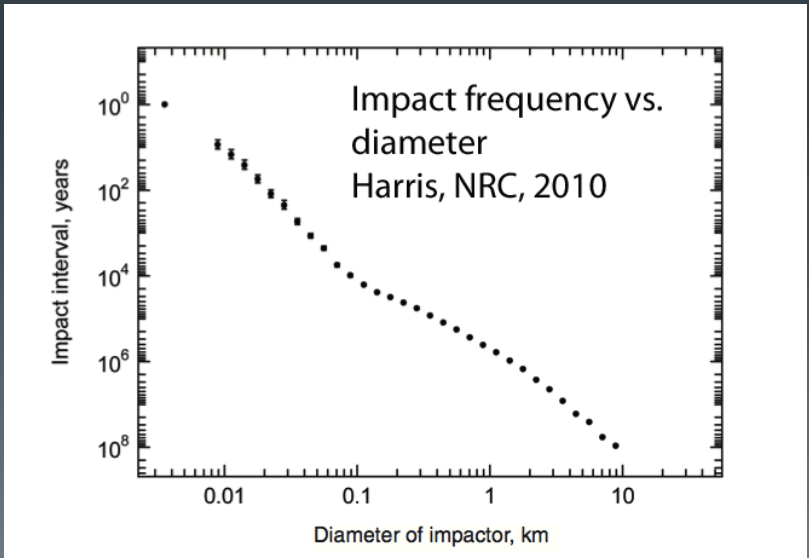
Identification and status:1

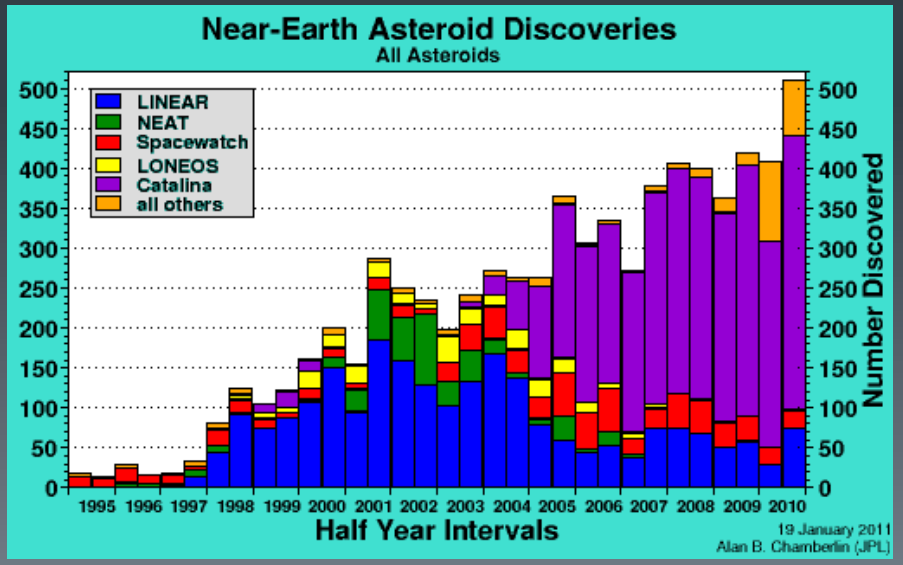
- Identification is by earth-based based telescope
- In 1980 we knew of only 97 NEOs. US Congresional action in 1998 and 2005 prompted higher discovery rates. 1998 mandate of identifying NEOs > 1 km has been achieved.
- Dim (low albedo) and often obscured by sun. An IR telescope in Venus orbit would improve detectability but would be expensive. Canadian NEOSSAT to fly this year or next at 800 km.

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

Identification and status: 2

- Approx 90% (909) of NEOs > 1 km (civilization-ending) have been identified (1998 mandate)
- Only 6900 of approx. 25000 NEOs > 140 m (city killers) have now been identified (e.g. Apophis, 300 m, close approach on 14 Apr 2029, returning again in 2036). 2005 mandate



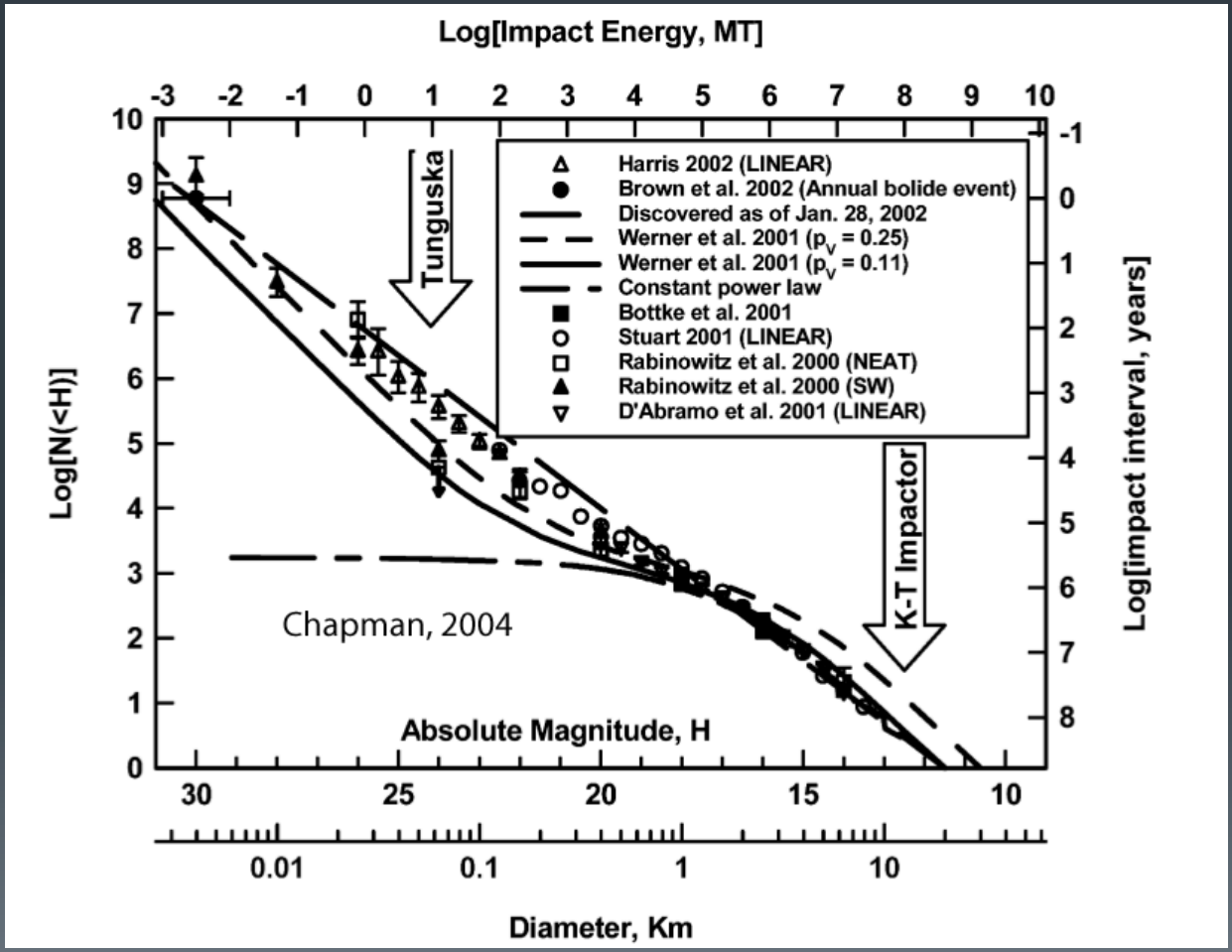


Identification and status: 3

- Earth impact database (www.passc.net/EarthImpactDatabase
-

Power-law characterizes size-frequency distribution

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space



NRC, 2010

Status

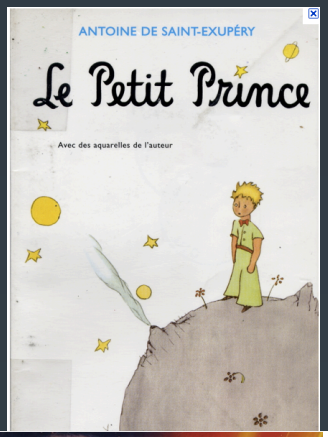
Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

NASA Twitter Feed, 740,000 followers

Asteroid mining. Recent announcement about a company that wants to mine asteroids, bringing them back to Earth for their rare elements.

POD, Options, Popular Culture

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space



- Precision orbit determination (POD) questions
- Options once identifed
  - Gravity tractor
  - Kinetic impactor
  - Nuclear weapons

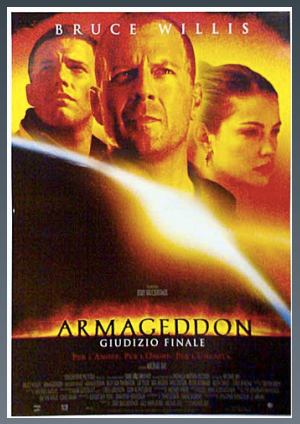
Intersection with popular culture:

UN Committee on Peaceful Uses of Outer Space

B612

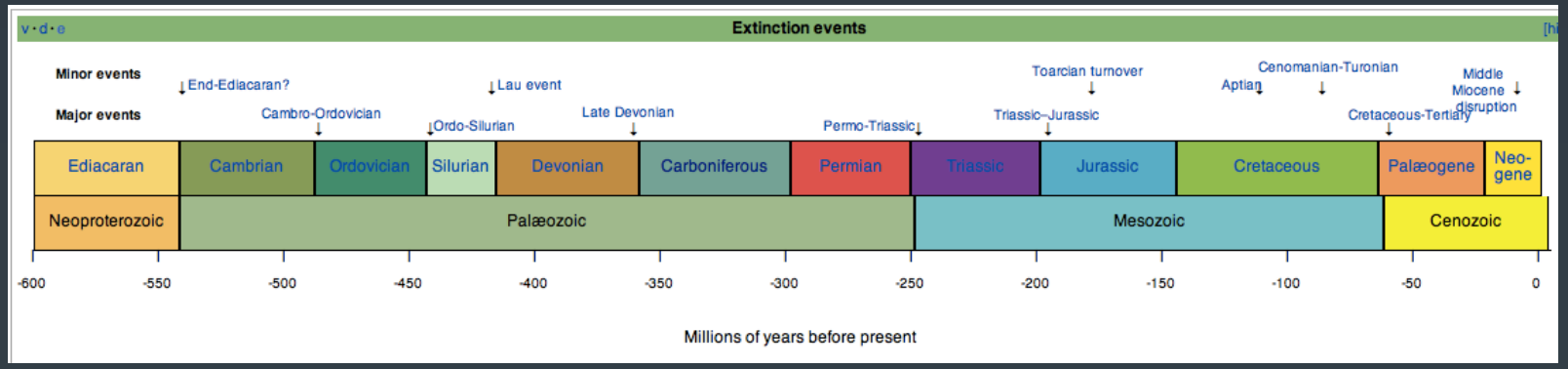
Armageddon

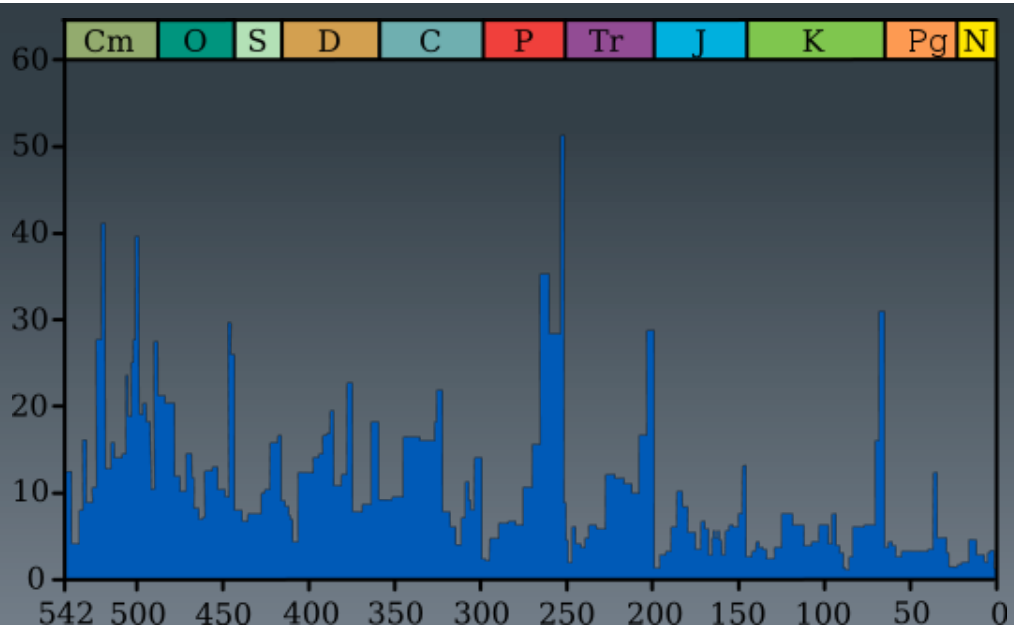
Deep Impact



NEOs yesterday: Mass extinctions and terrestrial impacts

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

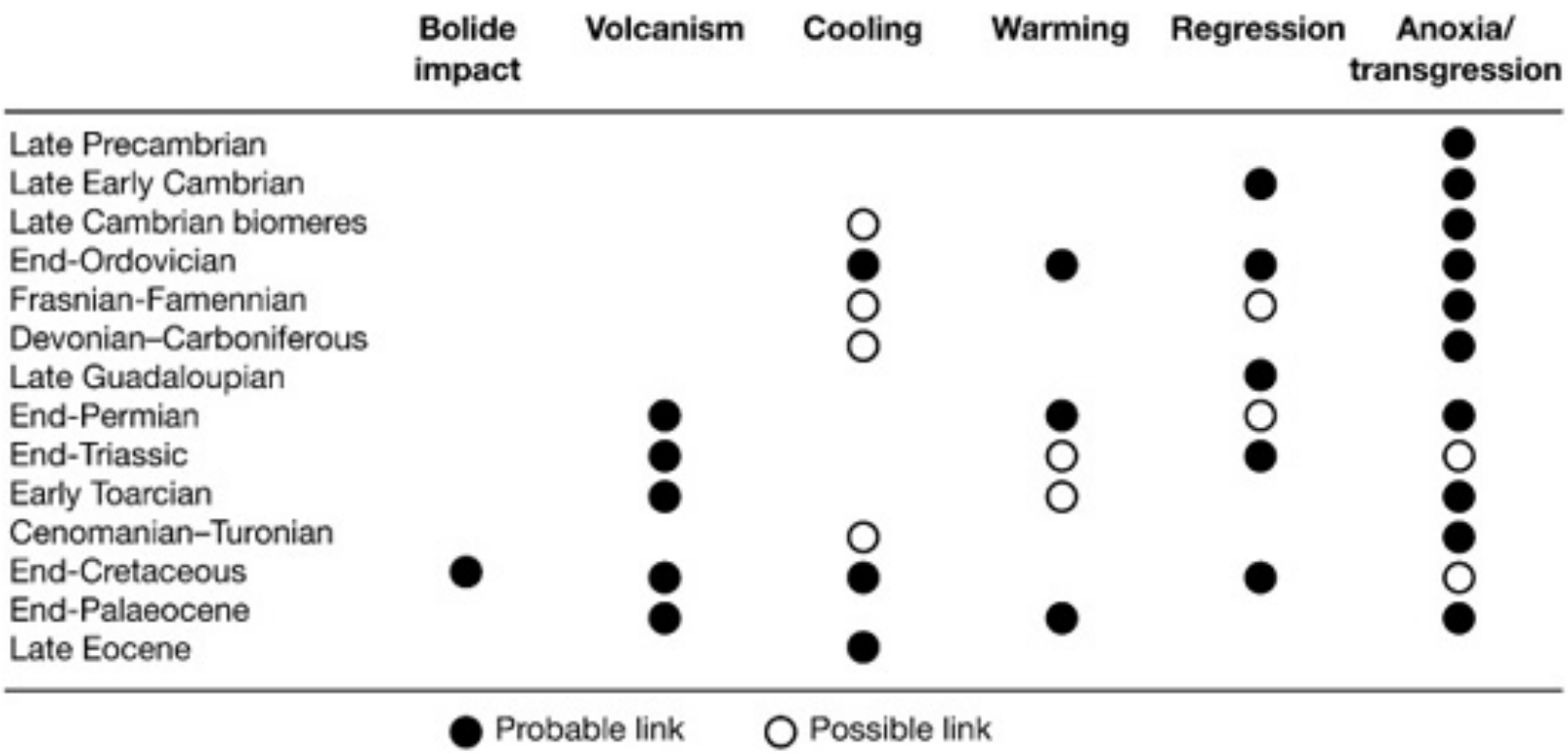




Hallam, 2004

Causes of Mass Extinctions

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

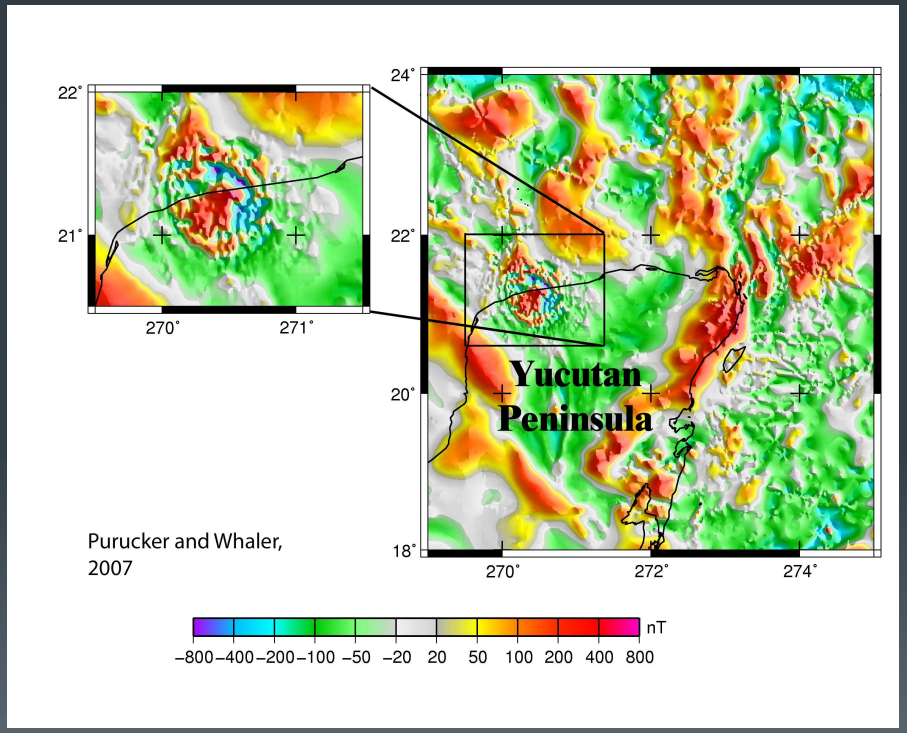


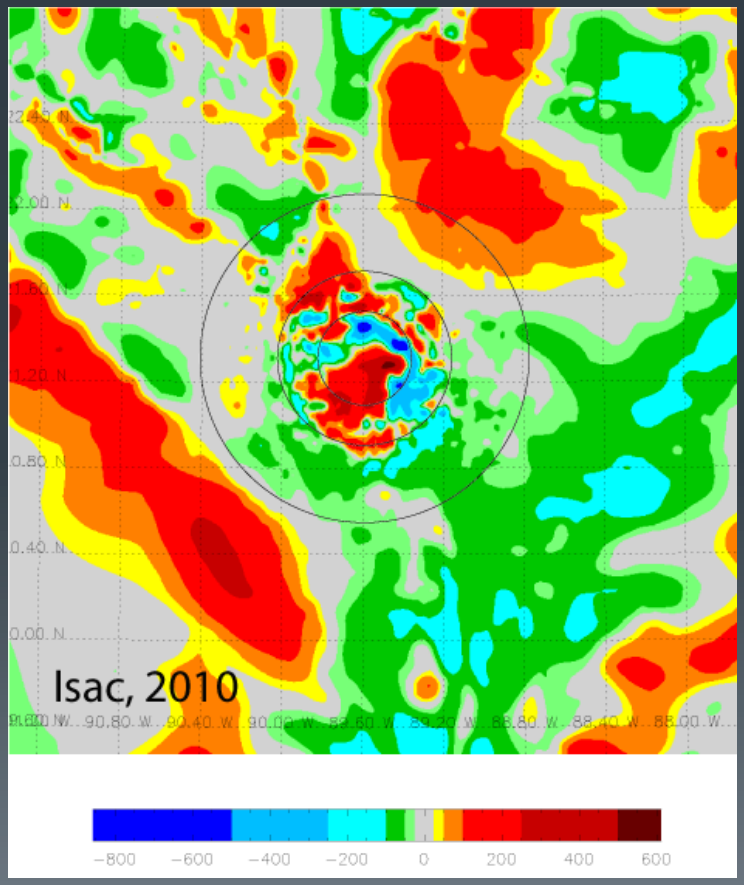
Hallam, 2004

Fossil NEOs-1

Chicxulub: Cretaceous terminal extinction

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

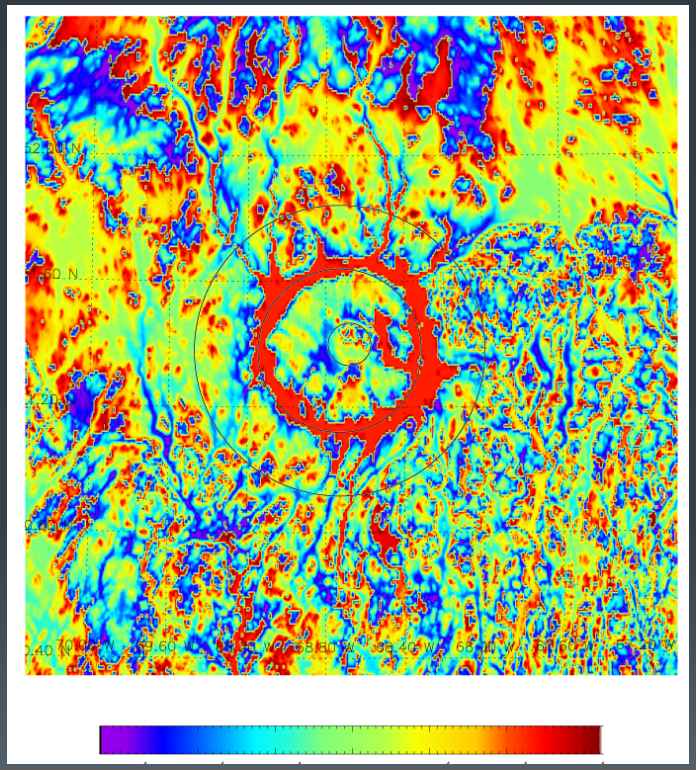


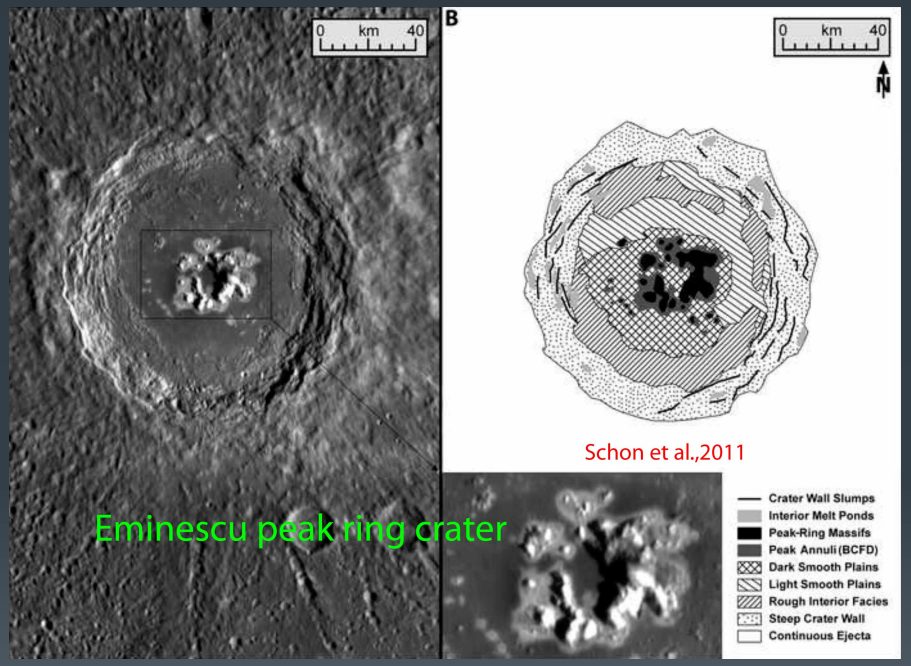


Fossil NEOs-2

Large impact basins on the Earth and Mercury

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space





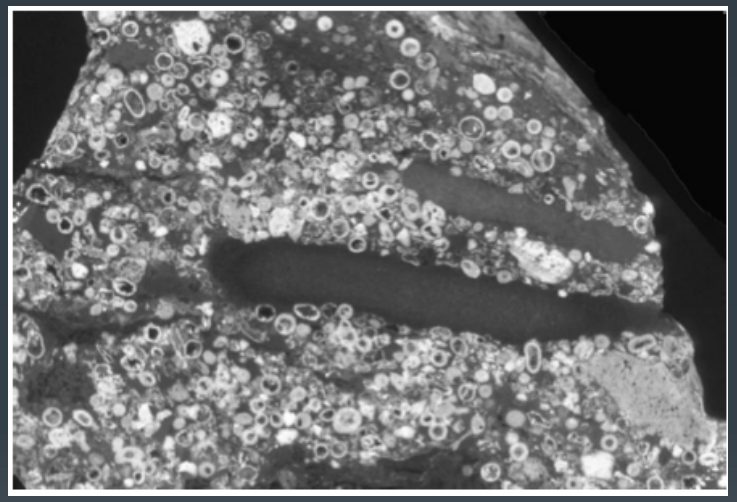
Manicougan: Earth

Eminescu: Mercury

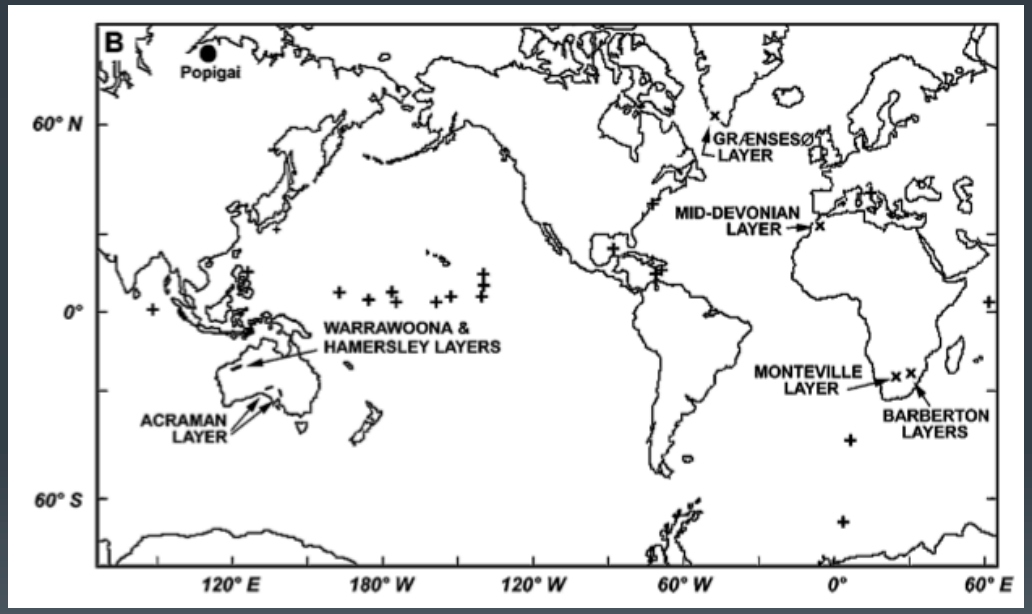
Fossil NEOs-3

Impact spherule layers as a tool for mapping old, large terrestrial NEOs in cases where impact site is not preserved

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space



Spherule-rich layer from Archean Jeerinah.

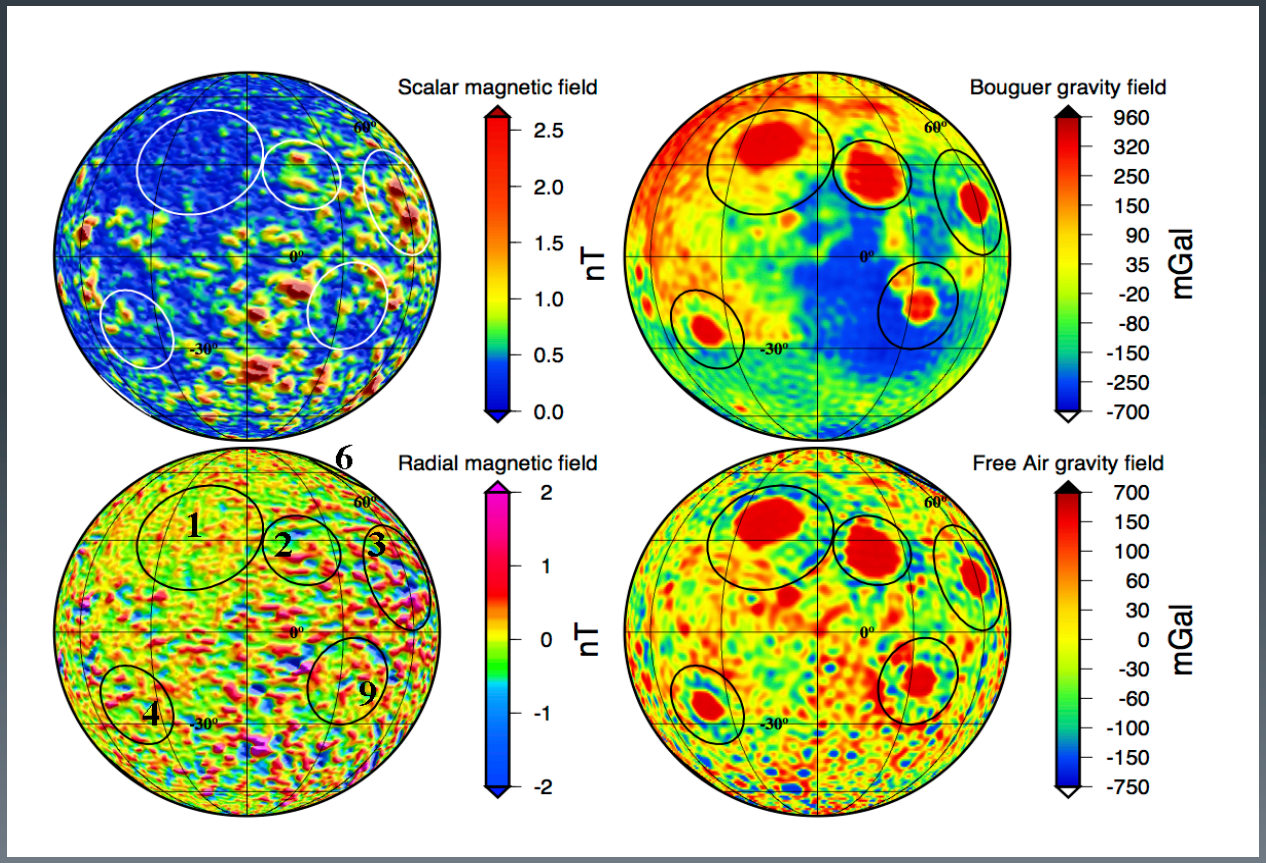


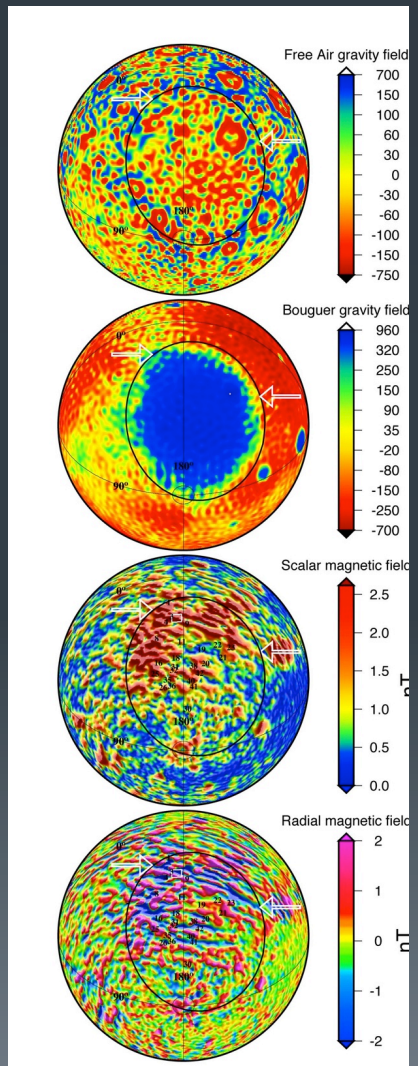
Known locations of Eocene (+) and older (x) layers.

NASA's GRAIL mission to study fossil NEOs

Planetary Geodynamics Lab, Code 698, Geodesy Geology Geophysics, Studying the Solid Earth and Planets from Space

Lunar gravity mission now underway
Map gravity field to > degree/order 180 (30 km +)
Technology (POD) and Science (mascon) goals





Summary

- NASA's latest target for human exploration, NEOs, represent the intersection of many scientific and popular themes, including astrophysics, nuclear buccaneering, and end-times entertainment. NEOs were much more common in the past, and have left scars (and research opportunities) on all of our solar system bodies. It's an exciting time to be a scientist!
- More realistically, NEOs also offer a target for robotic exploration and colonization. The ability to extract and fashion local resources will be easiest on the NEOs, and represents a critical step towards making a space colony self-sufficient, and self-replicating.